Abstract

The motivation of this thesis is to propose a robust control technique for a laser beam system with target estimation. The laser beam is meant to track and fall on a particular portion of the target until the operation is accomplished. There are many applications of such a system. For example, laser range finder uses laser beam to determine the distance of the target from the source. Recently, unmanned aerial drones have been developed that run on laser power. Drone batteries can be recharged with power supply from laser source on the ground. Laser is also used in high energy laser weapon for defence applications. However, laser beams travelling long distances deviate from the desired location on the target due to continually changing atmospheric parameters (jitter effect) such as pressure, temperature, humidity and wind speed. This deviation error is controlled precisely using a lightweight fast steering mirror (FSM) for fine correction. Furthermore, for a moving target, minimizing the deviation of the beam is not sufficient. Hence, in coarse correction, the target has to be tracked by determining its position and assigning the corresponding azimuth and elevation angles to the laser sources. Once these firing angles are settled within an accuracy of ± 3 mrad, the effort for minimizing the beam deviation (fine correction) takes place to improve the accuracy to ± 10 μrad.

The beam deviation due to jitter effect is measured by a narrow field of view (NFOV) camera at a high frame rate (1000 frames per second), which takes one frame to compute this error information. As a result, controller receives error information witha delay from NFOV. This data cannot be modelled for prediction and hence, a few promising data driven techniques have been implemented for one step ahead prediction of the beam deviation. The predictions are performed over a set of sliding window data online after rejecting the outliers through least square approximated straight line. In time domain, methods like auto-regressive least square, polynomial extrapolation (zeroth, first and second order), Chebyshev polynomial extrapolation, spline curve extrapolation are implemented. Further, a convex combination of zeroth order hold and spline extrapolation is implemented. In frequency domain, Fourier series-Fourier

transform and L-point Discrete Fourier Transform stretching are implemented where the frequency component of the signal are analysed properly and propagated for one step ahead prediction. After one step ahead prediction, three nominal controllers (PID, DI and DLQR) are designed such that the output of FSM tracks the predicted beam deviation and the performances of these controllers are compared.

Since the FSM is excited by high frequency signals, its performance degrades, which leads to parameter degradation in the mathematical model. Hence, three adaptive controllers have been implemented, namely, model reference adaptive control (MRAC), model reference adaptive sliding mode control (MRASMC) and model following neuro-adaptive control (MFNAC). The parameters of the FSM model are degraded up to 20% and the model is augmented with cross coupling terms because the same mirror is used for horizontal and vertical beam deviation. With this condition, the tracking performance and control rate energy consumption of the implemented adaptive controllers are analysed to choose the best among them.

For a moving target, in coarse correction, two tracking radars are placed to measure the position of the target. However, this information is assumed to be noisy, for which an extended Kalman filter is implemented. Once the position of the target is known, the desired firing angles of the laser sources are determined. Given the laser source steering mathematical model, a controller is designed such that it tracks the desired firing angle. Once the residual error of the coarse correction settles inside ± 3 mrad, fine correction takes part to reduce the residual error to ± 10 μrad. The residual error magnitude of the proposed mechanization was analysed for a moving target by perturbing the FSM model by 20% and zeroth order hold predictor with different combinations of angle tolerance and frame tolerance.